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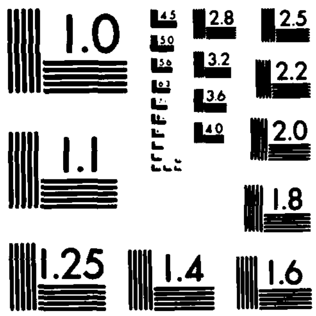

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FOREIGN TECHNOLOGY DIVISION

THE EFFECT OF PULSE CURRENT ON THE ELECTRICAL STRENGTH
OF HIGH-VOLTAGE MODULATOR TUBES

by

L.A. Varakin, Yu.I. Yesikov, P.V. Poshekhonov

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А а	*А а*	A, a	Р р	*Р р*	R, r
Б б	*Б б*	B, b	С с	*С с*	S, s
В в	*В в*	V, v	Т т	*Т т*	T, t
Г г	*Г г*	G, g	У у	*У у*	U, u
Д д	*Д д*	D, d	Ф ф	*Ф ф*	F, f
Е е	*Е е*	Ye, ye; E, e*	Х х	*Х х*	Kh, kh
Ж ж	*Ж ж*	Zh, zh	Ц ц	*Ц ц*	Ts, ts
З з	*З з*	Z, z	Ч ч	*Ч ч*	Ch, ch
И и	*И и*	I, i	Ш ш	*Ш ш*	Sh, sh
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Н н	*Н н*	N, n	Э э	*Э э*	E, e
О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

*ye initially, after vowels, and after ъ, ь; e elsewhere.
When written as ё in Russian, transliterate as yё or ё.

RUSSIAN AND ENGLISH TRIGONOMETRIC FUNCTIONS

Russian	English	Russian	English	Russian	English
sin	sin	sh	sinh	arc sh	$\sinh^{-1}$
cos	cos	ch	cosh	arc ch	$\cosh^{-1}$
tg	tan	th	tanh	arc th	$\tanh^{-1}$
ctg	cot	cth	coth	arc cth	$\coth^{-1}$
sec	sec	sch	sech	arc sch	sech^{-1}
cosec	csc	csch	csch	arc csch	csch^{-1}

Russian	English
rot	curl
lg	log

GRAPHICS DISCLAIMER

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THE EFFECT OF PULSE CURRENT ON THE ELECTRICAL STRENGTH OF HIGH-VOLTAGE MODULATOR TUBES

L.A. Varakin, Yu.I. Yesikov, P.V. Poshekhonov

Ryazan'

High-voltage modulator tubes are very considerably different in electrical strength from the simple vacuum gaps. Thus, for example, the gap composed of flat molybdenum electrodes with a distance of 10 mm is broken down with a voltage 250 kV. The breakdown voltage of such a length of the gap between the anode of the tube and the electrode nearest to it and the electron grid is a total of 30-50 kV.

The studies conducted at a number of electrovacuum plants showed that the lowering of the strength occurs due to a whole number of simultaneously acting factors: the high temperature of the electrodes, their dustiness by evaporation products of the oxide cathode unique to the configuration of electrodes, the presence of insulators, and so on. A number of the factors connected with the

operating mode of the tube is established. During the time of passage of the pulse of anode current, due to its low density (2-3 A/cm^2), the arcing of the cathode, as the initiator of the breakdown, is eliminated. On the other hand, the effect on the electrical strength of the pulse parameters is revealed. By means of special counters it was established that the determined part of the breakdowns is directly connected with the passage of the pulse current. It would be possible to consider that this is caused by an increase in temperature of the electrodes; however, simple calculations showed that both on the front and during passage of the current pulse, the pulse temperature of the electrodes does not exceed several degrees.

In all appearance, the observable effect is connected with the appearance in the tube of charged particles - positive ions [1]. A certain clarity in understanding the mechanism of appearance of ions and their effect on the breakdown would be given by an experiment on the establishment of the dependence of electrical strength of the tube on the current pulse duration. In particular, such an experiment would allow judging as to whether the appearance of the ions is connected with the bombardment of the anode by electrodes of the rear front of the current pulse, when the anode is bombarded by electrodes of high energy, or the output of the ions is mainly affected by the duration of the bombardment because of the growing release of the gas in the process of the bombardmennt itself. It should be noted that

the direct measurements of ion currents in the dynamic operating mode of the tube, according to obvious considerations, are virtually impossible. Therefore, any check of the assumption about the role of ions in the development of the breakdown can be fulfilled only by indirect experiments.

The experiment was conducted on nonaged tubes of the type GMI-90. The scheme of the test was no different from the standard schemes of modulators with partial discharge of the storage capacitor (Fig. 1). With a change in the duration of the current pulse τ, the pulse frequency f was changed in a way that the product τf remained constant. This provided a constancy of the average magnitude of the scattered power and, consequently, the temperature of electrodes of the tube. The change in pulse duration in a range of 2-8 μs corresponded to a change in the repetition frequency of 500-125 Hz. In the process of the duration (130 hours) of the tube test, every 20 minutes its operating mode was changed, every hour the test cycle was repeated, and thereby the independence of results of the experiment of the gradual ageability of the tube was ensured. The electrical strength was estimated according the quantity of breakdowns totaled for one cycle of tests for each pulse duration.

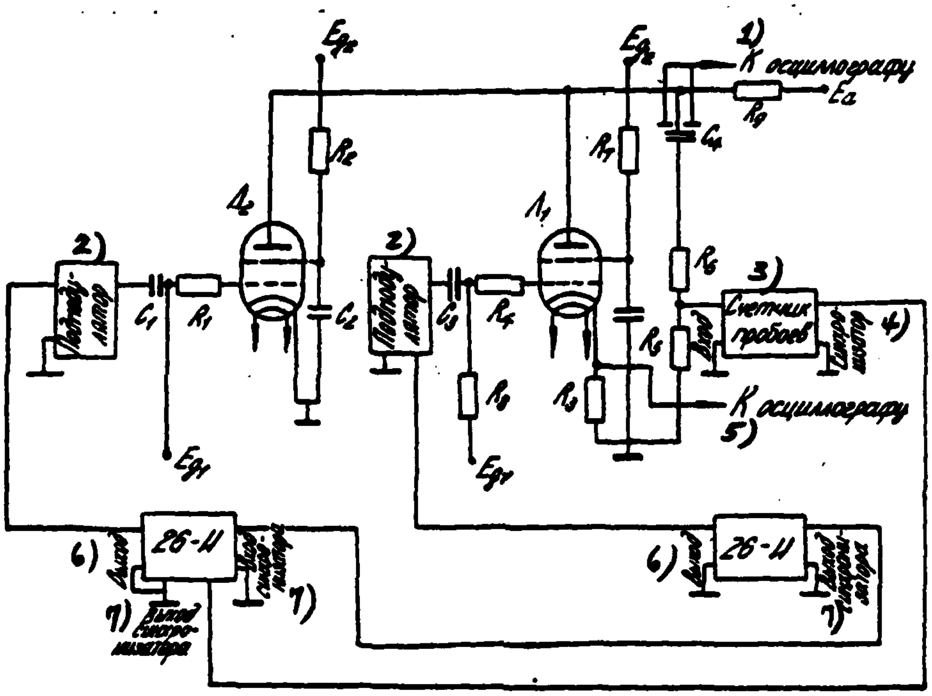

Fig. 1. Experimental diagram of the apparatus. Key: 1) To oscillograph; 2) Submodulator [driver]; 3) Counter of breakdowns; 4) Synchronizer; 5) To oscillograph; 6) Output; 7) Output of synchronizer.

A two-channel counter using decatrons was used for counting the breakdowns. All the breakdowns were recorded on the first channel, and recorded on the second channel were only those breakdowns which were developed 50 μs after passage of the pulse (breakdown in the pause between pulses - n_p). As is evident from the normalized curves

(Fig. 2), with an increase in the pulse duration the number of breakdowns in the tube is increased. This is especially acutely manifested for breakdowns developed following the passage of the pulse n_i.

The obtained result indicates the considerable importance of processes connected with the electron bombardment of the anode. An increase in the duration of the bombardment leads to the amplification of these processes and lowering of the electrical strength of the instrument.

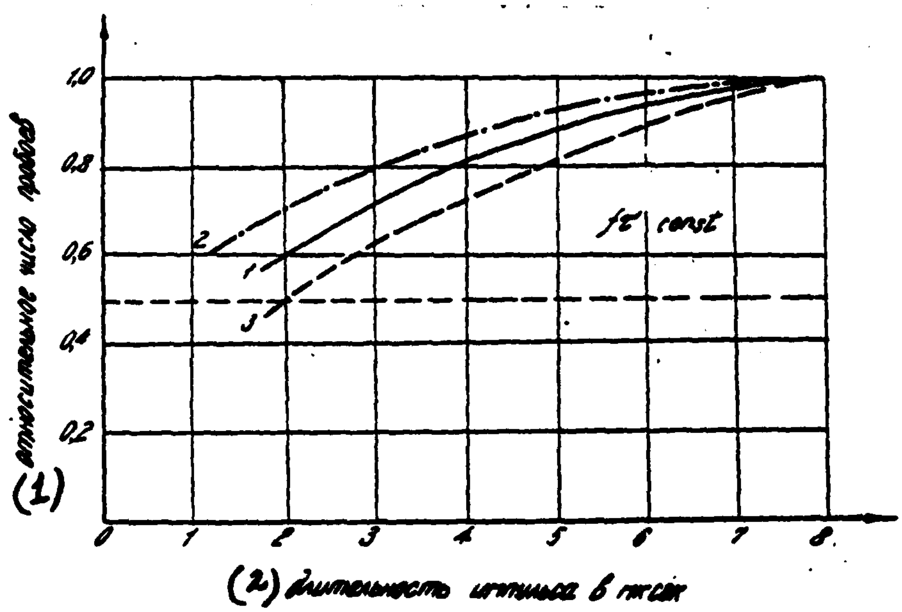

Fig. 2. Dependence of number of breakdowns in tube GMI-90 on the current pulse duration: 1 - curve of change of total number of

breakdowns; 2 - in the pause between pulses; 3 - in first 50 μs after cutoff of the pulse. Key: (1) Relative number of breakdowns; (2) Duration of pulse in μs.

We can assume that the effect of bombardment is indicated, first of all, in the shortest time after cutoff of the pulse, when in the gap there is a sufficiently large number of ions, and the complete voltage of the power source E acts on the anode. This proposal can be checked experimentally, having created conditions in the tube in which the anode voltage is increased after each pulse not immediately but after a certain time interval τ_1, during which deionization of the gap can occur.

In conformity with these considerations, the necessary lowering of the voltage in the experiment described below was reached owing to the fact that the tube L_2 (Fig. 1) being studied was included into the test circuit in parallel with the more electrically stable tube L_1. Both tubes operated alternately on the common load R_4 in such a way that when the current through tube $Л_2$ was cutoff, the tube L_1 was opened. Thereby the increase in the anode voltage on the tube being tested, after passage of the current pulse, was artificially delayed by a magnitude of the duration of the current pulse of the auxiliary tube τ_1 (Table 1).

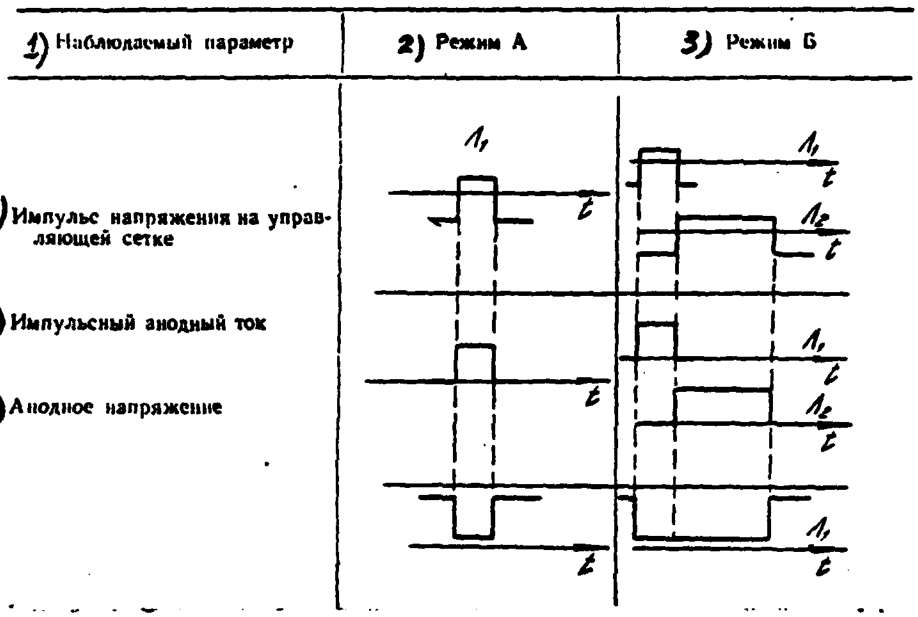

Table 1. Key: 1) Observed parameter; 2) Mode A; 3) Mode B; 4) Voltage pulse on control grid; 5) Pulse anode current; 6) Anode voltage.

The matching of the trailing front of the pulse of tube L_2 with the leading front of the pulse of tube L_1 was ensured in that the cutoff pulses on control grids of both tubes were suppressed from individual submodulators, the trigger pulses of which were taken krom two I-26 oscillators. One of them operated in the mode of the slave trigger with a delay over the output for the time of the pulse duration of the investigated tube L_2. The matching and shape of the pulses were monitored by the oscillograph SI-1 and were completely

satisfactory. The well-aged tube GMI-90 was selected as the auxiliary tube L_1. The *nonaged* tubes GMI-83, GMI-5, GMI-10, and GMI-90 were investigated. The pulse duration of the tubes investigated was 2 μs and of the auxiliary tube - 5 μs at a repetition frequency of 500 Hz.

The experiment was conducted in the following way. In the process of the long (30-50 h) test, every 30 minutes there was established either a special (Table 1 - mode B) or normal operating mode of the tube (mode A). In the latter case the auxiliary tube was cut off. The cycle of tests was repeated every hour. The electrical strength was estimated according to the number of breakdowns in the tube for the whole time of the test with respect to elements of the cycle. Table 2 gives results of the conducted experiment.

1) Тип лампы	2) Режим А		3) Режим Б		Время работы лампы, ч 4)
	n_i	n_p	n_i	n_p	
ГМИ-83	6,3	4,5	0,75	1,85	32
ГМИ-5	1,7	1,25	0,36	0,54	44
ГМИ-10	1,37	0,56	0,37	0,25	64
ГМИ-90	4,5	3,7	1,2	1,3	50

5) Примечание. n_p — 6) усредненное количество пробоев в паузе между импульсами за 1 ч;
n_i — 7) усредненное число пробоев, зарегистрированных в течение 50 мксек после окончания импульса.

Table 2. Key: 1) Type of tube; 2) Mode A; 3) Mode B; 4) Operating time of tube, h; 5) Note; 6) averaged number of breakdowns in the pause between pulses for 1 h; 7) averaged number of breakdowns recorded during 50 μs after completion of the pulse.

From an analysis of results of the test, it follows that if the anode voltage of the tube, after the passage of the current pulse through it, remains for 5 μs the same as that during passage of the pulse (mode B), then a sharp lowering of the total number of breakdowns is observed. The fact that together with a considerable lowering of the breakdowns during pulse n_i there is observed a certain lowering of the number of breakdowns in the pause between the n_p pulses is noteworthy.

The experiments conducted are indicative of the presence in high-voltage modulator tubes of the so-called "anode effect," according to which very significant for the development of a breakdown are processes occurring on the surface of the positive electrode. By not taking direct participation in the development of the prebreakdown process, the electrons bombarding the anode are the cause which "uncouples" these processes. It is possible that as a result of the electron bombardment, the surface of the lanode becomes a more active source of the positive ions, which directly determine the further development of the prebreakdown processes. It is known that even an absolutely clean surface, under conditions of technical vacuum (10^{-} mm Hg) is covered by a layer of gas in the course of time. A constantly growing film containing carbon appears on the

electrodes [2]. In modulator tubes the contamination process is intensified, to a considerable degree, by the constant spraying of evaporation products of the oxide cathode. With electron bombardment of the anode, there occurs decomposition of the film with the release of a sufficiently large quantity of gas and its subsequent ionization by electrodes near the anode surface. A direct release of ions from the anode surface is possible [3].

If we take the viewpoint, which at present receives ever more wider recognition, that the breakdown is developed due to the progressively growing autoelectronic current, then the role of the positive ions, most probably, must be reduced to the intensification of the field near the emitter. According to works [4-5], such an intensification occurs because of the existence of the space positive charge between the electrodes.

By using the rate of recovery of insulation properties of a vacuum gap after breakdown, A. Meitland [6] arrived at the conclusion that the worsening of the strength of the gap after breakdown is connected with the appearance of positive charges on dielectric inclusions always available on the cathod surface. These charge cause the appearance of the autoelectronic current in conformity with the Molter effect, which explains the comparatively long time during which the gap remains in a state of reduced electrical strength. An

electrical strength was observed during the first 5 μs after the breakdown.

Results of this work are contained within the framework of proposals of A. Meitland. If the current pulse is considered as a unique breakdown, after which separate currents of the cathode become centers of the autoelectronic current, then the lowering of the anode voltage for the time when these centers are most active (3-5 μs) allows preventing the development of the prebreakdown processes, which leads to a sharp lowering of the number of breakdowns in the tube. A decrease in the breakdowns which are the result of the passage of the current pulse should lead to a decrease in the number of breakdowns and to the pause between the pulses, since for the complete recovery of the electrical strength, a comparatively long time, measured in many hundreds of microseconds, is necessary. Therefore, the breakdowns in the tube are frequently observed not in the form of single breakdowns but in the form of a series following each other.

From what has been said above, it is possible to draw the following conclusions. In the operation of a pulse high-voltage electron tube with an oxide cathode, its electrical strength considerably depends on processes which occur in it after the bombardment of the anode surface by electrons of current of the

operating pulse. Several microseconds after passage of the pulse, the tube remains in a state of a sharply reduced electrical strength. The strength of the tube is lowered with an increase in the pulse duration to a considerably greater degree than with the corresponding increase in the train frequency.

It is assumed that the electron bombardment of the anode is connected with the formation of positive ions, which are determined in the subsequent developmennt of the breakdown.

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